PLC PROGRAMMING AND CONTROL OF SEMI-AUTOMATED

PREPREG CHOPPING MACHINE

N. S. KAMBLE

All India Shri Shivaji Memorial Society's Institute of information technology, Pune, Maharashtra, India

ABSTRACT

Composite fibers are globally used in voluminous applications. The defense and aerospace industry is the largest consumer of prepreg for civil aircraft, military, jet, helicopters, aero-engines or space satellite launchers. Prepreg is a term of preimpregnated composite fibers in which a matrix material such as epoxy, silicon carbon fiber, etc. With the developme in technology in cutting where laser cutting has taken the lead being the most accurate yet unaffordable and time consuming. This paper refurbishes an old cutting technique merged with the automation technology, which gives an all new affordable solution to cutting of bulk materials, with good accuracy and less time consumption.

KEYWORDS: Prepregs, Fibers, Cutting, Automation, PLC

INTRODUCTION

Prepreg is a term for preimpregnated composite fibers where a matrix material, such as epoxy, is already present. The prepreg has a plastic peel over it so the sheets do not stick to each other. The prepreg sheets are bundled and rolled in a spool form. The prepreg is to be cut into chops. This approach requires research, concept development, sequencing and programming and control of a Special Purpose Machine (SPM) to feed and precisely cut the prepreg. These prepregs are used in the form of chops in the realization of random fiber molded products. The cutting techniques in use for prepregs are ultrasonic cutting and laser cutting which prove to be expensive with low productivity.

MOTIVE

Automation or automatic control is the application of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching in telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or diminished human intervention. Some processes have been comprehensively automated. The biggest contribution of automation is that it extricates labor, however, it is also used to save energy and materials and to improve quality, accuracy and precision. The control systems are built around special devices, designed to operate industrial machines, and processes. These devices are Programmable Logic Controllers (PLC) and Programmable Automation Controllers (PAC).

Programmable logic controllers are modular, industrially hardened computers which perform control functions through modular input and output (I/O) modules. The modularity of PLC allows the user to combine generic I/O modules with a suitable controller to form a control system specific to his needs. The operation of a controller by envisioning repeatedly performs three steps (a) Reads inputs from the input modules (b) Solves pre-

programmed control logic (c) Generates outputs to output modules based on the control logic solutions. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC memory. The PLC continuously monitors the inputs nd activates the outputs according to the control program.

This requires sequential and logical thinking, such a modular approach has the advantage that the initial configuration can be expanded for other future applications such as multi machine systems or computer linking which has led to the selection of PLC programming and control for this paper.
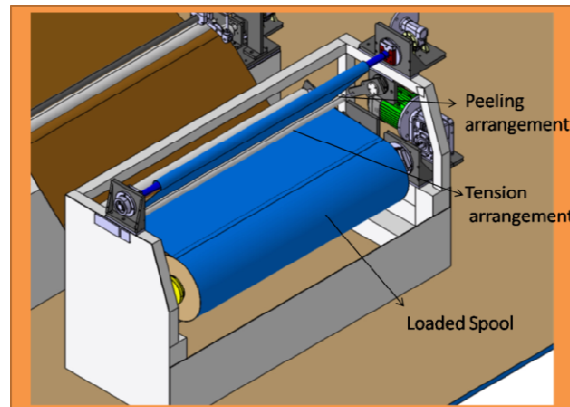
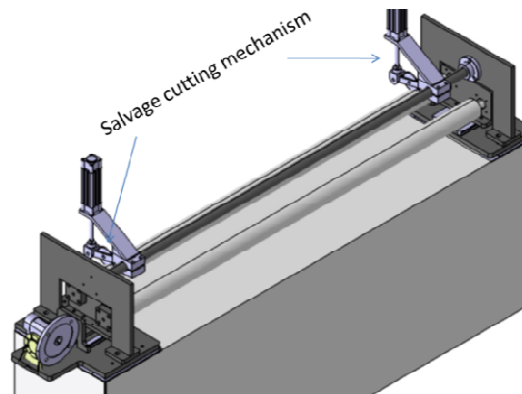

Figure 1: The Setup of Prepreg Chopping Machine

Figure 2: Loading Station

Figure 3: Salvage Cutting Machine

SYNOPTIC REPRESENTATION

The slitting and reeling machine evaluates the current "state of the art" for the dissertation, pointing out major methodological flaws or gaps in the processes. The existing technology to cut prepreg composite fiber spools into pieces are ultrasonic cutting and laser cutting. Ultrasonic cutting operation is way expensive and laser cutting operation has its own disadvantage that it evaporates/burns the material due to heating. Thus, there is a need of developing a machine which can precisely cut the spool without burning the material with less cost. PLC programming and control reduces the time, effort and labor involved in the process.

The prepreg is provided in a spool form, which weighs 80 kgs, the length of the shaft of the spool is 1500 mm, and the diameter of the shaft is 300 mm. The prepreg sheet has to be cut into specifications given by the user which will range from 10 mm to 100 mm. Time taken per cut should range from 5 secs to 50 secs depending on the width of the cut. The machine cuts any size within the range from 10 mm to 100 mm by directly programming in the control unit. To maintain production rates of chops for the size of 10mm carbon phenolic prepreg of 0.4 mm thickness 10kg/mm is cut and an accuracy of the machine below 10 microns is obtained.

The materials are sourced and assembled as per the model. All the electrical components are fixed and wired. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC memory. The PLC unit is interfaced. The material is loaded and the program is run, the faults are recorded and measures are taken to correct the faults.
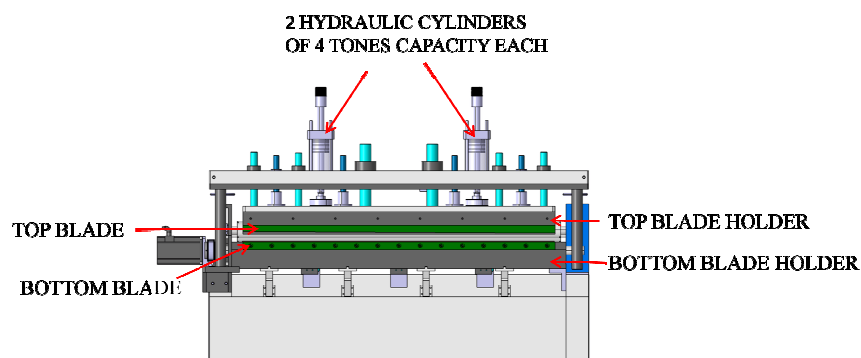

Figure 4: Longitudinal Cutting Station of Prepreg

PREPREG CHOPPING MACHINE

The prepreg chopping machine is an SPM which generates chop to the defined size of the material prepreg. The material is wound in the form of a spool, this spool has a length of 1500mm, maximum weight of the prepreg is 80 kg, and the prepreg wound spool diameter is 300 mm. The prepreg chopping machine generates the chops of size varying from 10mm by 3mm to 100mm by 100mm. The machine has the features to cut to variable size as per the range defined in the inquiry. The figure 1 shows the developed machine.

PLC PROGRAMMING AND CONTROL

On assembling the mechanical components of the machine, the PLC programming and setting up the control mechanism of the machine is carried out. The machine layout in figure 4 shows the loading station where the material is loaded and the plastic peel is removed.

This station has two motors M5 & M6. The motor M6 unwinds the material from the spool, while motor M5 rolls the plastic peel of the material onto a

Shaft and is collected in a spool form Motor M4 is present at web alignment station. Control station 1 is a feeding and cutting station, this station consists of 2 arrangements. The first arrangement is the conveyor arrangement for feeding of the raw material, the conveyor is moved forward by the motor M3. The second is the cutting system where the material is cut into strips of specified width as mentioned by the user. Motor M7 controls the power pack which controls the hydraulic cylinders that controls the cutting. The layout also shows the PLC control panel and the HMI unit.
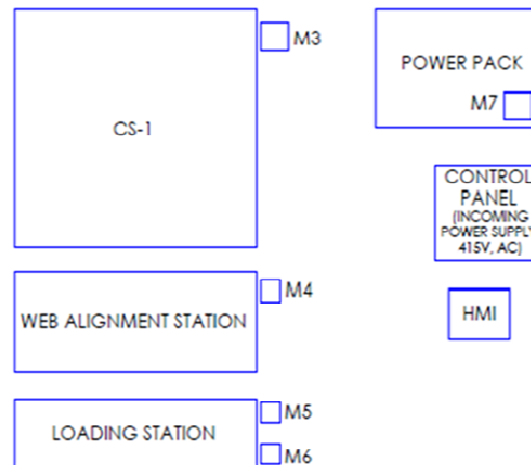

Figure 5: Machine Layout

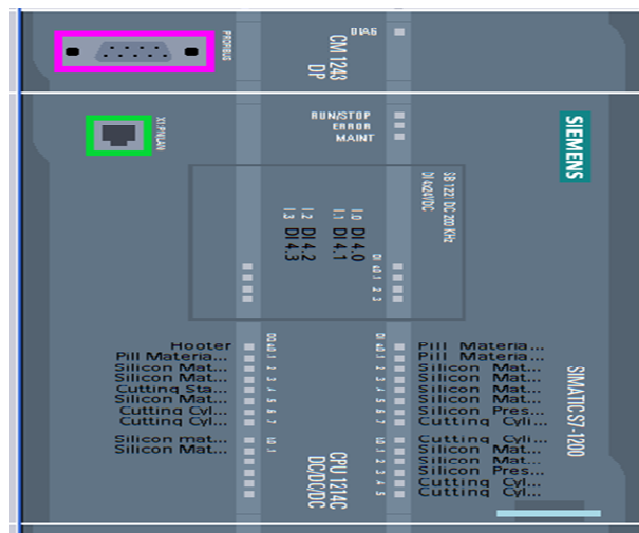**Figure 6: PLC Interfacing Diagram of Simatics S7-1200**

The control system for semi automated prepreg chopping machine consists of a collection of electronic devices and equipments which are placed to ensure the stability, accuracy and smooth transition from unloading to cutting of material.

Field devices used are operator panel, motors, sensors, switches, etc. Manual control are obtained by push buttons and prepping.

Prepping the prepreg chopping machine is done manually before the PLC program is put into action and the automation of the chopping machine begins. The Spool is loaded on the spool unwinding system, the peel is removed from the raw material and stuck to the peel off the roller. The material is passed under the tension roller onto the salvage cutting station and on the feeding station, through the web alignment, where it is fixed by the adjustable free loader and the conveyor. After the above conditions are taken care of, the start button is pressed, which starts the automation of the machine.

- **Control At Station 1**

The material begins to unwind, while passing under the tension roller, while maintaining tension of the material. The tensioning arrangement has a dead weight of 8 kgs, it also has two proximity sensors at each end, if the material being unwound is loose the tension shaft is lowered, which is sensed by the proximity sensors.

The sensors provide feedback to the PLC and the motor is stopped if the material is too tight and started when the tension shaft returns to home position.

- **Control at the Peeling Station**

As the material begins to unwind, the plastic cover is removed and one edge of the peel is stuck to the roller when passing under the tension roller while maintaining tension of the peel. The tensioning arrangement has two proximity sensors at each end, if the material being unwound is tight the tension shaft is raised which is sensed by the proximity sensors. The sensors provide feedback and the motor is stopped if the material is too tight, and started when the tension shaft returns to home position.

Table 1: Specifications of Motors

Sr. No.	Description	Make	Qty	Rating
1	AC Induction Motor	Bonfiglioli	2	100 rpm, 28 Nm,0.5 HP
2	Motor	Bonfiglioli		BN 71B4,
3	Synchronous Servo Motor	Siemens	1	7.3Nm 3000rpm

Table 2: Specifications of Controller

Sr. No.	Description	Make	Qty	Rating
1	Simatics S120 Control Unit (Servo)	Siemens	1	CU310 PN Control Unit (with Compact Flash card)
2	Simatic S7 1200 (PLC) Controller	Siemens	1	-
3	Simatic HMI	Siemens	1	KTP600 Basic color PN Touch Screen + 6 Function Keys,5.7" LCD TFT display, 256 colors
4	SMPS	Siemens	1	Input: 120/230 V AC, 50/60 Hz, 1.2 A/0.67 A, Output: 24 V DC/2.5 A
5	UPS	Emerson	1	1KV/800W
6	Transformer	Neel	1	1KVA 50 Hzt 430-230 V
7	Compressor with Air Dryer	ELGI	1	4kw,5.6 HP,7.5 kgf/cm^2 Pressure

Table 3: Specifications of Reed Switches

Sr. No.	Description	Make	Qty	Rating
1	Reed Switch SP1,SP2(Pressure Pad1)	Festo	2	24V DC
2	Reed Switch SP3,SP4(Cutting Bled1)	Festo	2	24V DC

- **Getting the Material Ready for Cutting**

Salvage cutting station is introduced to cut the unwanted edges of the material and give the material a straight shape. This station consists of the engage and disengage push buttons, this process is started and stopped manually. Web alignment station consists of 2 sensors on the shaft at a distance of 1 meter from each other, this controls the alignment of the material. If the material is misaligned, the feeding

Station motor moves in reverse direction and again moves forward till the material is adjusted. A sensor at the cutting station senses the material, this activates the pressure pad, the pressure pad fixes the material to the cutting table and the cutting operation takes place when the hydraulic arrangement is activated.

- **Specifications of Electrical Components**

This PLC system is of modular type comosed of specific hardware building blocks (modules), which plug directly into a proprietary bus a central processor unit (CPU), a power supply unit, input-

Table 4: Specification of other Electrical Components

Sr. No.	Description	Make	Qty	Rating
1	Push Buttons	Siemens	6	-
2	Emergency Push Button	Siemens	1	-
3	Fuse	Siemens	2	5Amp
4	Power Contactors	Siemens	3	440V,9Amp,24VDC Coil
5	Over Load Relays	Siemens	3	1.5-6.5
6	MCB 4 Pole	Siemens	1	230/415V AC
7	MCB 3 Pole	Siemens	3	230/415V AC
8	MCB 2 Pole	Siemens	2	230/415V AC
9	Pilot Relays	Omron	24	24V DC,2Amp
10	Indication Lamps	Siemens	3	230V AC,50 Hz
11	Rotary Switch	L&T	1	440V,30Amp
12	Wires	Finolex	-	-
13	Panel Light	Philips	1	230V AC,50 Hz
14	Socket Board	Anchor	1	230V AC,50 Hz

Table 5: Specifications of Proximity Switches

Sr. No.	Description	Make	Qty	Rating
1	Proximity Switch S1 (Spool Empty)	Omron	1	24V DC
2	Proximity Switch S2 (Raw material tight/lose)	Omron	1	24V DC
2	Proximity Switch S3 (Plastic peel Tight /losel)	Omron	1	24V DC
3	Proximity Switch S4& S5 (Web Alignment)	Omron	2	24V DC
4	Proximity Switch S5 (Material Present)	Omron	1	24V DC

Output modules I/O and a program terminal. The specifications of various electrical components viz. controllers, motors, sensors, read switches, and other components are specified in table 1-6. Table 2 represents the specifications of the selected PLC control unit Simatic S120 and controller HMI is Simatic HMI with touch screen and 6 function keys which has a 5.7' display. The table 1 gives the description of the motors used. The AC induction motor is used for unwinding the raw material and the second induction motor is used for removing the peel from the material. The Siemens motor is used

for the functioning of the conveyor which acts as a feeding station. Table 3 represents specifications of the components which provide manual input. There are 4 push buttons provided at

Station one to manually control the forward or reverse motion of the unwinding of the spool and winding of the peel off the shaft. The salvage cutting is also controlled manually by push button. One push button is provided for Auto/Manual operation. One emergency stop button is provided for stopping the machine. Table 4 gives a description of reed switches used. Reed switch 1 provides feedback to the PLC by sensing the position of the pressure pad. One reed switch senses that the pressure pad is at the top position while the other reed switch senses if the pressure pad is in the down position. Table 4.4 provides the description of the proximity sensors. These proximity sensors are used for feedback. The sensor S1 senses that spool is empty or loaded, sensorS2 senses if the raw material is tight or loose, i the sensor S4 & S5 sense the alignment of the material.

Table 6: List of Inputs and Outputs

S. No	Inputs	Outputs
1	Lose Peel material	Hooter
2	Tight Peel material	Peel motor forward
3	Silicon material lose	Peel motor reverse
4	Silicon material tight	Silicon motor forward
5	Silicon material shift right side	Silicon motor reverse
6	Silicon materia shift left side	Silicon materail shift forward motor
7	Silicon material present	Cutting station conveyor start
8	Cutting cylinder up	Cutting Cylinder power
9	Cutting cylinder down	Cutting cylinder down

- **Input Output List**

Based on all the electrical components used in the field and their processes, the inputs and outputs for PLC programming are decided and listed in table 6. The sensors and reed switches provide inputs to the PLC by checking the specified conditions. The unwinding station consists of one sensor which sense the condition of the material, whether it is loose or tight. The PLC controller Siemens S7 1200 is shown in figure 5. There are 9 inputs and 9 outputs which are interfaced to the PLC controller. The Siemens S7 1200 controller consists of a power connector, memory card slot under, top door, removable user wiring connectors (behind the doors), status LEDs for the on-board I/O.

SEQUENCE OF OPERATION

The following is the sequence of operation

- Unwinding of material

- Winding of plastic peel on the shaft

- Web alignment

- Feeding of material

- Fixing of material for cutting

- Cutting of material.

- PLC PROGRAM

There are a total of 9 inputs and 9 outputs which are listed in table 4.5. The PLC unit is interfaced and the sequence of operation is determined. The program for the main functions of the machine to be carried out are described briefly.

Program for Peel off Operation

Figure 5 shows the rung for the program of the Peel off system. The motor is set in the forward direction if the following conditions are set.

- The Auto Pill Material Adjustment forward

- The main engine stop button is activated and ready for use.

  OR

- Auto Manual is off.

- Pill motor forward push button is on.

- Emergency stop pushbutton is ready for use

  OR

- Manual pushbutton of the forward motor is on

- **Program for Web Alignment**

The program rung for the web alignment adjustment in shown in figure 5. The conditions set when the web alignment ie. the material is adjusted to the left or right are :

- Auto/Manual button is on.

- Prepreg(Silicon) material on the left side is on

- Prepreg(Silicon) material on the right side is off

- Auto Start is on

- Emergency stop pushbutton is ready to be used.

- **Program for Feeding of Material at Cutting Station Conveyor**

Figure 7 shows the rung of the program that enables the feeding of the material.The proximity sensor present on the conveyor station checks for the presence of material and activates the conveyor. The motor controlling the conveyor starts and the conveyor starts moving. Hence the material present on the conveyor is fed to the cutting station.

The conditions set for the conveyor to start feeding should be :

- Manual Conveyor is on.

- Count of the cuts is off.

- Emergency stop pushbutton is ready to be used.

  OR

- Conveyor start is on.

- **Program for Cutting**

The healthy condition for cutting is checked and feeding of the material is clocked, once the required feed as per required cut is obtained the trigger is activated, the hydraulic cylinder comes down and cutting is done Figure 4.6 shows the rung of the program that enables the cutting of the material.

The following conditions are set for the cutting operation to be carried out

- The cutting hydrauluc cyliner is at home position ie. at TDC.

- The emergency stop button is ready to use

  OR

- Manual Cutting Cylinder power Command is on.

  OR

- The cutting cylinder power command is on.

CONCLUSIONS

The PLC programming & control of a semi-automated prepreg chopping machine on a Siemens Simatic S7 1200 controller, has been discussed so far. The inputs and outputs are devised and listed in table 4.5. The interfacing has been discussed in section 4. Out of 4 recent processes researched for cutting of prepreg the method of feeding utilized by Lectra Vector Auto Fx was found most suitable for the prepreg cutting. Out of the 6 techniques researched for cutting, a similar cutting technique which works on the principle of a scissor was selected.

Achievements

- As per the synoptic representation the aim of achieving 10mm to 100mm strips has been achieved.

- Time taken per cut ranges from 5 secs 50 secs per cut depending on the width of the cut as described by the user.

- The material provided in the spool form has uneven edges, hence a salvage cutting arrangement which cuts uneven edges was added to the system, which is achieved by 2 cutting discs placed at a distance from 1 mtr from each other.

- At the loading station, the material was found to unwind faster than the material being fed which resulted in collecting of unwound material, to rectify this the tension arrangement which stops the motor when the material is found to be loose.

- During the cutting operation the material was found to be misaligned, which led to the cut strips being rejected, to correct this the web alignment system was introduced, which detects if the material is shifted to the left or right side. In this case the movement of the roller is reversed.

The Limitations Faced

The panel consists of too much wiring, which makes the system complicated. The troubleshooting of the system is a very time consuming affair. If modification is required, the machine has to be stopped and wiring has to be traced to make the required changes. Machine downtime is very long when any problems occur. In terms of maintenance an electrician should be well trained and skillful in trouble shooting the control system.
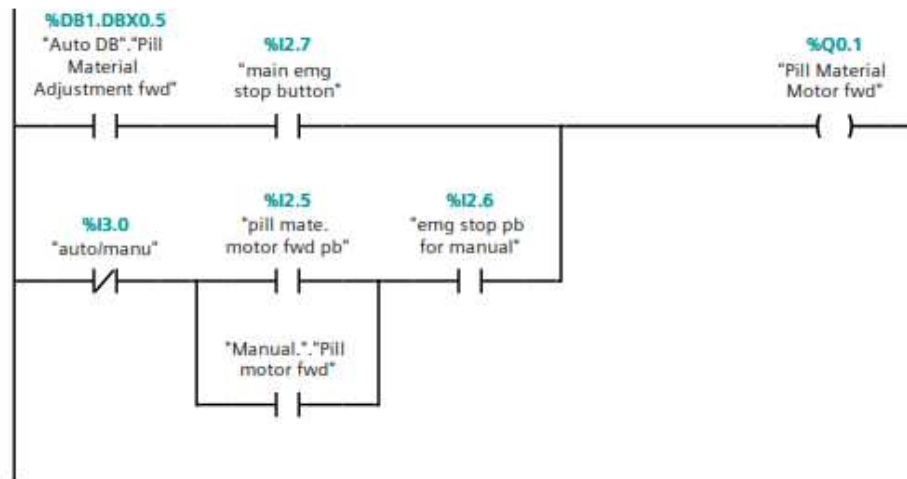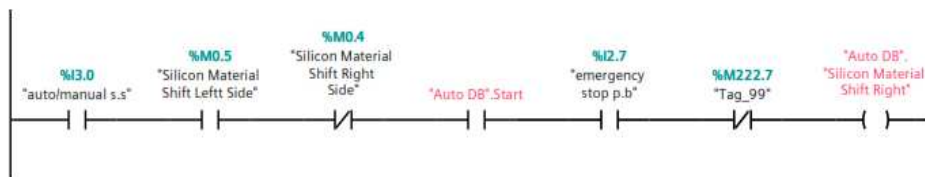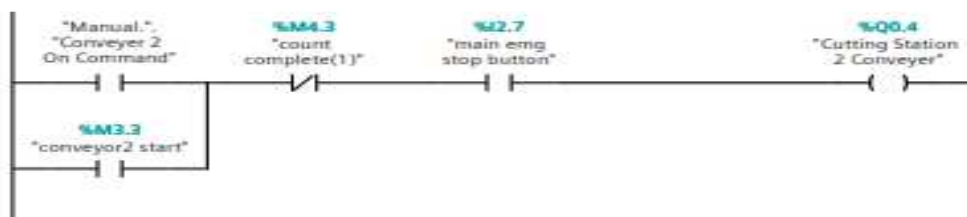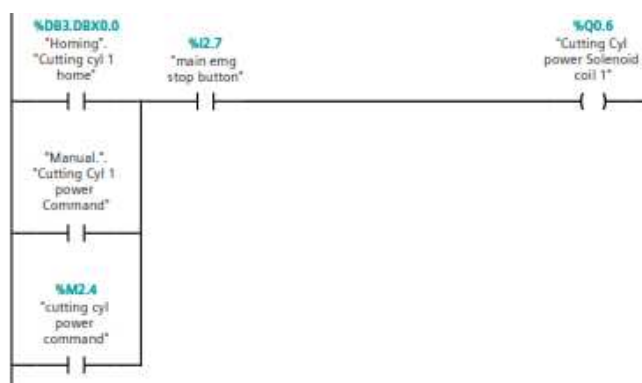

Figure 7

Figure 8

Figure 9

Figure 10

REFERENCES

1. *Development of PLC-based Tension Control System REN Sheng-le*, LU Hua, WANG Yong-zhang, FU Hong-ya Department of Mechanical Engineering, Harbin Institute of Technology, Harbin 150001, China.*

2. *Rewinding paper safely, Safety Hazards HSE priced and free publications Website: www.hsebooks.co.uk (HSE priced publications are also available from bookshops and free leaflets can be downloaded from HSE's website: www.hse.gov.uk.)Scott Appleyard, Andrew Braund, Richard Brown, Derek Coulson, George Dews, Paul Grady, Kevin Graham, Phil Green, Bud Hudspith, Andrew, Johnson, ReijoLaine, Nigel Mills, Paul Spencer, Terry Willan.*

3. *http://www.reinforcedplastics.com/view/2926/automating-cutting-of-composites 14 June 2008 Amanda Jacob*

4. *Handbook for composite reinforcements edited by Stuart.M.Lee,Wiley VCH publishers.Inc, Library og Congress, Cataloging in publication data.*

5. *A knowledge-based system for conveyor equipment selection Daniel J. Fonseca*, Gopal Uppal, Timothy J. Greene Department of Industrial Engineering. The University of Alabama, Tuscaloosa 35487, USA*